論　文　の　要　旨

題　目　Topology optimization of macro-/micro- structures for dynamic problems
（動的問題に対するマクロ・ミクロ構造のトポロジー最適化）

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This dissertation presents robust topology optimization of macrostructures and microstructures for dynamic problems, and the topology optimization of piezoelectric smart structures is also performed. The motivation for this research and some fundamental concepts are briefly introduced in Chapter 1. The other chapters are organized as follows.

Chapter 2 investigates robust topology optimization of structures subjected to unknown-but-bounded dynamic loads/ground accelerations. The robust topology optimization formulation considering uncertain-but-bounded excitation is presented using the ellipsoidal convex model. Then the single-loop reformulation of the originally nested problem on the basis of inhomogeneous eigenvalue analysis is proposed. Sensitivity analysis for the worst-case dynamic response is derived. Numerical examples are also presented to demonstrate the validity of the proposed method, and the obtained robust optimal solutions are compared with their deterministic counterparts.

Chapter 3 investigates a robust topology optimization method for designing the microstructures of PnCs by considering random-field material properties. The deterministic band analysis method of PnCs with the FEM is first presented. Then the stochastic response analysis method combining the EOLE method with the PCE approach for the random material property distribution is addressed. The robust formulation of the topology optimization for PnCs with uncertainties and derives the sensitivity analysis for the stochastic band gap response is proposed. Numerical examples is presented to demonstrate the validity of the proposed robust optimization method and discusses robust designs for different band gap orders and different waves propagating modes.

In Chapter 4, a phase-field-based topology optimization method of vibrating structures that reduces the dynamic performance variability under diffuse-region uncertainties is developed. Herein, the spatial distribution of the widths of diffuse regions in a multi-material structure is first represented by a random field and then discretized into uncorrelated stochastic variables using the expansion optimal linear estimation method; stochastic response analysis is then conducted with polynomial chaos expansion. The stochastic structural dynamic responses and the corresponding sensitivities are evaluated by polynomial chaos expansion based on finite element analysis at each sampling point. Numerical examples show that the proposed method generates meaningful optimal topologies for structural dynamic robust optimization problems with the framework of the phase-field method. The phase field-based method is applied into the robust topological microstructural design of PnCs under diffuse region uncertainties.

In Chapter 5, topology optimization of the electrode coverage over piezoelectric patches attached to a thin-shell structure is proposed to reduce the energy consumption of active vibration control under harmonic excitations. The constant gain velocity feedback control method is employed, and the structural frequency response under control is analyzed with the finite element method. In the mathematical formulation of the proposed topology optimization model, the total energy consumption of the control system is taken as the objective function, and a constraint of the maximum allowable dynamic compliance is considered. The sensitivity analysis for total energy consumption of the active control system is derived. Numerical examples are presented to demonstrate the validity of the proposed method, and the differences between the proposed optimization model and the traditional volume minimization model are also discussed based on the numerical solutions.

Finally, Chapter 6 summarizes the findings in this dissertation, and describes promising avenues to explore in future research.